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APPLIED MANUFACTURING RESEARCH
AND PROCESS DEVELOPMENT
DEPARTMENT 290

MEMORANDUM

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Transmittal of Applied Manufacturing Research
Department 290-2 Project Report No. AN61MD2014
1) Development of Optical Tooling Bar.

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APPLIED MANUFACTURING RESEARCH
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DEPARTMENT 290

Report No. AN61MD2014
DEVELOPMENT OF OPTICAL TOOLING BAR

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GENERAL DYNAMICS/ASTRONAUTICS
June 1961

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DEPARTMENT 290

ABSTRACT

This report is supplementary to AN59MD2005-1 discussing the first lightweight optical tooling bar of composite construction, kinematically designed specifically for use with the "Offset Line of Sight" Physi-Optical Tooling Dock. This report describes more recent developments respecting two prototype optical tooling bars of bonded sandwich construction.

The core material for the first bar was "Hexcel" 5052-H39 aluminum alloy honeycomb core, 1/4" cell size, .003" foil gauge, density 6 lb. cu. ft. The second bar provided a unique application for a relatively new core material known commercially as "Trussgrid". This is a corrugated core, also of 5052-H39 aluminum alloy, 3/32 height, .002" foil gauge, density 5.7 lbs. cu. ft. possessing unique qualities such as : inherent strength and rigidity, ease of fabrication and machining to close tolerances. This core material facilitated a unique feature in the design of the second bar providing an integral bed way for the rails with resulting weight saving and fabrication advantages.

Both bars have aluminum alloy facings and functionally, are an improvement over the original bar of extruded sections reinforced with side panels of phenolic honeycomb. Of the two bars discussed in this report, preference is given to the type using "Hexcel" honeycomb core bonded into an "I" section, built from extruded aluminum alloy "tees" top and bottom with a detachable rail bed way. It appears to have superior stability and dampening qualities.

From a fabrication and material cost consideration, the difference between the two bars under discussion is insignificant. The possibility of reducing fabrication costs appear practical through further experimentation.

Report No. AN61MD2014, Development of Optical Tooling Bar.
Further copies of this report are obtainable from Technical Services Department 290-3, Ext. 3791.

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TITLE

DEVELOPMENT OF OPTICAL TOOLING BAR

OBJECTIVE

To develop a second improved optical tooling bar for use with the "Offset Line of Sight System" of physi-optical* tooling, incorporating the following features:

a. Stand, 12 feet long (first one was 10 feet), of relatively lightweight construction, portable and supported at three points.

b. A full length bed way to support the carriage and optical components (jig transit and optical square); sighting height, 61" $\pm$ 1".

c. Stability to insure repeated optical readings quickly and precisely; and good dampening qualities.

d. Hydraulic system for raising and lowering casters to enable the bar to be positioned with ease for alignment of optical components with "Offset Line of Sight".

*Physi-optical practices at the Astronautics Division combine the use of specific physical measuring standards with optical instruments. By this, and the use of mechanical positioning devices which coordinate the optical instruments to the measuring standards, precise linear and angular dimensional control of positioning and alignment is achieved.

INTRODUCTION

The optical tooling bar with jig transit and optical square components is an important requirement of the physi-optical tooling system, which under continual development, promises added improvements in tool manufacturing and inspection techniques, with resultant savings in time and man power.

The bar is one of a series of developments (References 1, 2, 5, 8, and 9, page 8), introduced with the "Portable Physi-Optical Tooling Dock" shown in Fig. 1, all being inter-related to the "Offset Line of Sight System", successfully adapted by both the San Diego and Astronautics Divisions.

This report is concerned primarily with the previous development of an improved bar* designed with jig transit carriage and target holders. Two bars of varied design, using different aluminum alloy core materials in a sandwich type construction were developed.

*See Report No. AN59MD2005-1 for description of previous bar with kinematically designed jig transit carriage and target holders. Copies of this report are obtainable from Technical Services Department 290-3, Ext. 3791.

The first bar, (Fig. 7), was made from "Hexcel" (Ref. 3, page 8), 5052-H39 aluminum alloy, 1/4" -.003", 6 lbs/cu. t. honeycomb core (see Fig. 5), bonded into an "I" section using extruded "tees" top and bottom, bonded to .091" thickness aluminum alloy facings, (Fig. 6). A separate machined bed way was secured to the top, (Fig. 4).

The second bar, (Figs. 13 and 14, also Figs. 23 and 24), of distinct design having a thicker sandwich core, with no flanges and thinner facings, .040" with an integral bed way was made from "Trussgrid" corrugated core. This is a relatively new core material possessing unique qualities, such as: inherent strength and rigidity, ease of bandsawing and machining to close tolerance, (± .003") without difficulty, (see Figs. 9 to 12 inclusive). Its use led to the development of the integral bed way and the concept of embedding the rails in milled grooves which promises possible fabrication advantages and weight savings, (Figs. 16 and 17).

**Trussgrid Corrugated Core, 5052-H39 Aluminum Alloy 3/32" - .002" @ 5.7 lb/cu.ft. (Ref. 4, page 8).

CONCLUSIONS

a. Performance tests on the two bars indicate that functional objectives have been satisfied. The most important stability and dampening qualities of the honeycomb bar with detachable bed way proved superior to the corrugated core bar, attributable no doubt to the distinct design and constructional features of each bar, rather than to the type of core material used.

b. Costwise, the two bars are nearly equal, and without considering engineering and development changes, it is estimated that one composite bar incorporating selected design features from each, could be duplicated for not more than 600 man hours plus material costs of approximately $1200, the major item of expense being the core material.

c. The "Trussgrid" corrugated core has inherent structural qualities that permit certain advantages in design and also in ease of machining. Unlike the flexible type cores, it holds it shape, (with careful handling), and can be bandsawed or machined to close tolerances. In this particular application the advantages, while significant did not result in an improved bar, nor did it lower fabrication costs. Its use however influenced the improved design of the bed way, accounting for savings in both machining and assembly man hours.

   Bonding the rails in grooves milled in the core to receive them is a highly satisfactory feature, and led indirectly to the development by this department of a portable milling fixture, MLFX, used for milling the grooves to desired specifications. This eliminated extra handling, set-up time, and minimized costly machining operations, (Figures 15, 16 and 17).

d. The problem of portability and especially the positioning of the bar with its optical components into the basic line of sight, has been solved satisfactorily by installation of a hydraulic lift system which actuates three rams on which are mounted swivel casters. Control valves permit ram operational selectivity, a required factor in obtaining the desired alignment easily and quickly (Figures 18, 19 and 20).

RECOMMENDATIONS

It is recommended that:

a. The "Trussgrid" bar just completed by this department in the Physi-optics Instrumentation Laboratory be used with other components of the dock system for continued research and development in measurement systems and procedures.

b. The "sandwich beam" phase of the project under TAP No. 2014 change letter "B" to be continued in an effort to cut fabrication and material costs while the excellent stability and dampening qualities of the proven "honeycomb" bar, (Fig. 7) will be retained. This portion of the development will be undertaken by this department, (Plastics Section), who will use new plastic foam materials as substitutes for the aluminum core sandwich materials. In this connection, it is recommended that at least one bar with sandwich "beams or panels" (main center and side panels - sub-assembly only), be developed for evaluation. Construction of the beam, top and bottom, will be patterned after the highly satisfactory "honeycomb" bar. If successful functionally and costwise, other components of the bar (carriage and clamp assembly, support units, etc.) will be manufactured to complete the unit.

   If the bar proves to be unsuccessful with a foamed plastic type of sandwich, it is recommended future bars be made to the "honeycomb" bar specifications. Possible changes in bonding methods for simplifying fabrication and changes of the choice of sandwich materials should be considered. There is a possibility, for example, of using new adhesives that eliminate the need for autoclave facilities (relatively high pressures and heat for curing). Also to be incorporated in future bars are several design changes in the bed way assembly and in the leveling screw support details to minimize extensive machining operations.

c. Finally, per agreement with Tool Manufacturing it is recommended three additional bars of approval design be fabricated and furnished to Tool Manufacturing for use in their physi-optical dock areas. These bars should be made as part of Project No. 2015, (Ref. 5, page 8) and would supplement the honeycomb bar already in use.

DEVELOPMENT

The original concept of the tooling bar and its components as outlined in Report No. AN59MD2005-1, (Ref. 2 page 8), and demonstrated in the first prototype bar, met design objectives satisfactorily with two exceptions. First, the stability and vibrational dampening qualities of the bar, especially in the area of the single screw point support, were not entirely satisfactory. Secondly, the bar lacked the necessary retractable caster features required for the final positioning into the line of sight.

About the time the bar was completed, (August 1959), new materials relative to sandwich construction were being introduced and through consultation with manufacturers concerned regarding applications of these materials for bar improvement, it was decided a bar using "Hexcel" honeycomb core should be developed which resulted in Project No. 2014 being initiated.

The main beam and side panels were to be made from a single sandwich with relatively thick facings, reinforced on the top and bottom with extruded "tees". All parts were to be made of aluminum alloy and bonded together with adhesives. The core was to be filled with plastic foam in specified areas. A sectional view of the sandwich would resemble an "I" beam with a stem of approximately 6-3/8"; height 35½" and the flanges, 9 inches. A plate was provided on top of the beam for securing a detachable bed way assembly, 12 feet long, (Figs. 2, 3, 4, and 6).

Trundle type bars combined with the use of the short instrument stand, (see Fig. 21), were also considered, but discarded in favor of the unitized bar, complete within itself.

Preliminary sketches of the bar were submitted to Tool Design Department 402-0, and working drawings were prepared, (TD7-1076B, later changed to IJ-70927, 8 sheets). A tool for bonding the beam components together was also designed to this department's specifications, BNTO, TD7-1076B, (See Figure 22).

The bar was evaluated and found to be highly satisfactory functionally, stability and vibrational dampening qualities were excellent. Labor costs however due primarily to unfamiliarity with untried fabrication techniques were high. The procedures had to be developed progressively, and as a consequence, a seemingly unrealistic expense was reflected. The cost did however compare favorably with the quotation by an outside vendor for development of a sandwich panel alone.

It was at this stage of the project that this department was made aware of the new corrugated aluminum alloy core known as, "Trussgrid". This material possessed inherent qualities that promised design and fabrication advantages. Its application in a tooling bar was discussed and subsequently approved for development.

The design and construction concept was changed to take advantage of the unique properties of the corrugated core. The sandwich beam was made of sufficient thickness, (9 inches), to accommodate an integral bed way having steel rails bonded therein. Normally these rails were fastened with screws to a detachable bed way. Bonding the rails eliminated a relatively costly machined bed way as a separate sub-assembly, (see Figures 4, 8 and 17).

The main objective at that time, as now, with the recently proposed use of new plastic foam material, (change letter "B" of the project), was to lower fabrication costs, while retaining the highly acceptable functional qualities of the honeycomb bar.

Design sketches for the "Trussgrid" bar, and a fabrication procedure flow chart were completed and approved in November 1960. The core material was ordered, and during the latter part of January 1961 work started on the bar. Its details were fabricated and assembled entirely by personnel of this department in the laboratory, with the exception of bonding operations which had to be accomplished in the autoclave at Plant 1, San Diego Division.

The core blocks were bandsawed to size on a Model 36W DoALL Machine. A special metal cutting blade (3/4" - 4 teeth per inch) normally used for cutting honeycomb core was used for straight cuts. The blade was run backwards at 2500 to 3000 feet per minute.

A regular metal cutting blade (1/2" - 10 teeth per inch), was used in the conventional manner at the same speed for contour sawing operations.

The bar was completed in May 1961, (see "Conclusions" page 2) of this report.

RESULTS

Two relatively lightweight and portable tooling bars of varying design, material and construction have been completed with good results. Valuable knowledge and experience has been gained in the design and manufacture of bars of this type.

Both bars of bonded sandwich construction are acceptable for use in production and demonstrate the values possible from research and development of this nature. Each bar possesses several tried and proven features that will contribute to the quality of future bars, and conversely, each has some features to be avoided. Also there is room for further development and simplification of adhesive bonding procedures and perhaps use of other types of materials in the sandwich in order to lower material and fabrication costs.

VALUE ANALYSIS

The tooling bar is one of several components of the physi-optical tooling dock system undergoing continued research and development. A thorough, realistic value analysis is impractical at this time until the system as a whole is completed and finally evaluated. It is however visualized that approximately 50% reduction in tool manufacturing man hours can be realized through use of bars in the system.

REFERENCES

1. Cost Improvement Proposal C.I.P. No. 55-01707, "Optical Method for Establishing Perpedicular Planes to a Basic Line of Sight without Blocking Line of Sight".

2. Astronautics Division, Department 290, Report No. AN59MD2005-1, "Optical Tooling Bar, Development of".

3. Hexcel Products, Inc. Main Office: 2332 Fourth Street, Berkeley 10, California, Regional Office: 1025 West Arbor Vitoe, Inglewood, California

4. General Grid Corporation, Main Office: 713 Stokes Road, Army Chemical Center, Maryland, Regional Office: 5591 Baja Drive, San Diego 15, California.

5. Astronautics Division, Department 290, Report** No. AN61MD2015, "Physi-Optical Tooling Dock".

6. Astronautics Division, Tool Design Sketch, IJ-70927, Optical Tooling Bar, 8 sheets.

7. Astronautics Division, Tool Design Sketch, TD7-1076B, Bonding Tool (BNTO).

8. Astronautics Division, Department 290, Report No. AN59MD9002A* Optical Square Support Adapter for Offset Line of Sight.

9. Astronautics Division, Department 290, Report No. AN59MD2017*, Low Cost Optical Square for Offset Line of Sight.

*Copies of these reports are obtainable on request to Technical Services Department 290-3, Ext. 3917.

**Not yet complete, to be published later.

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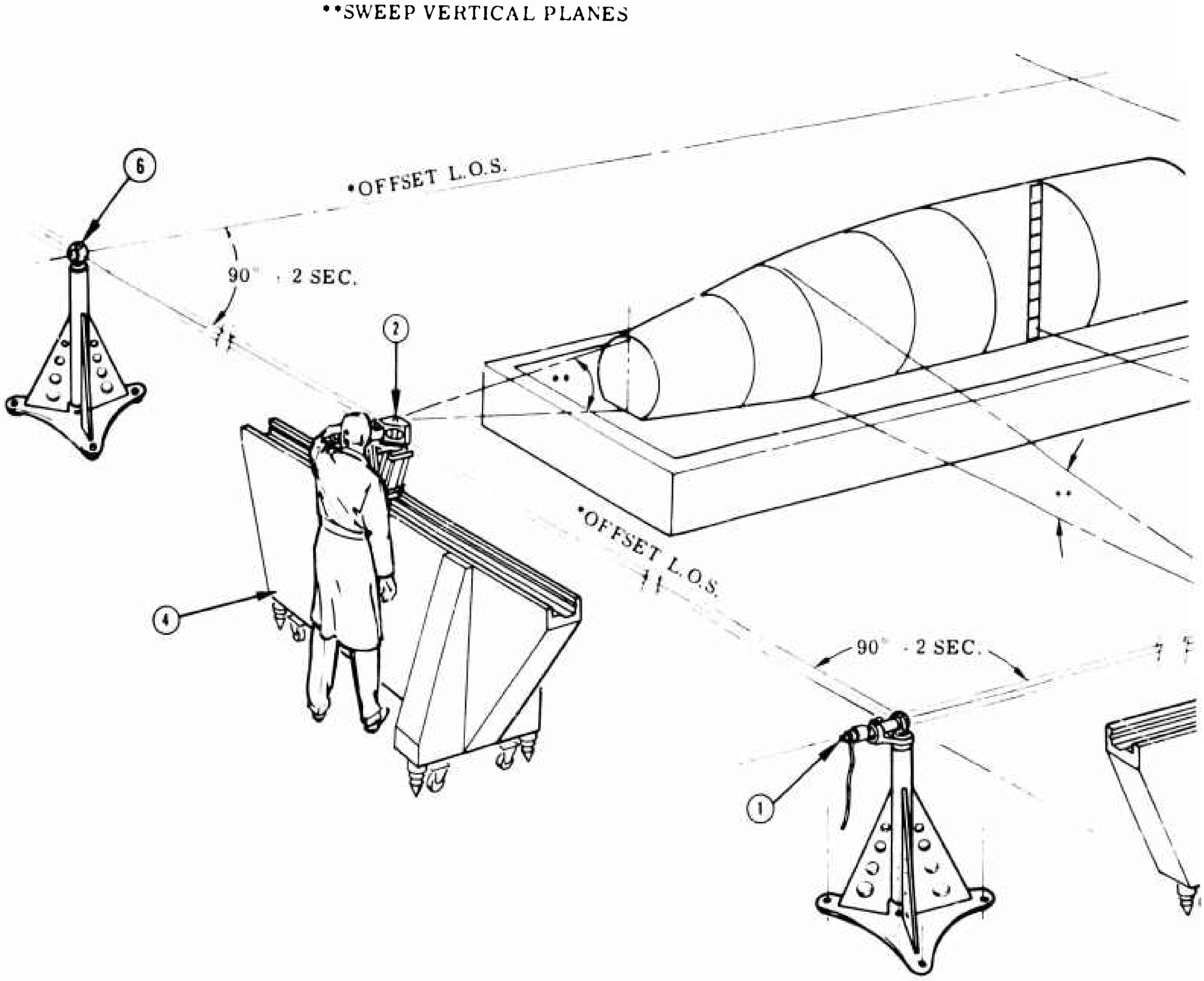


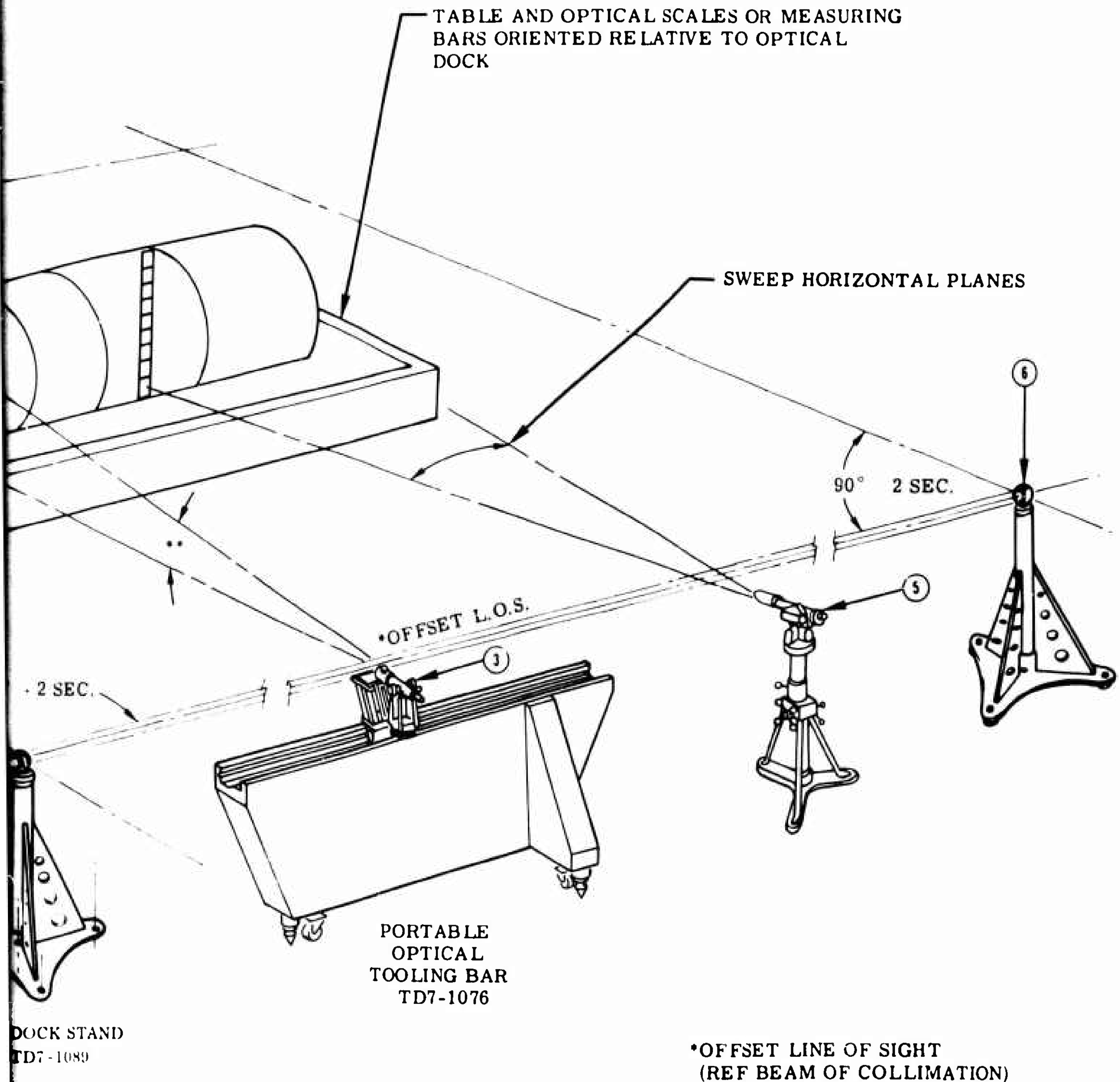
OPTICAL DOCK STAND
TEST TD7-1089

Legend:

1. K and E Alignment Telescope with built-in auto-collimation illumination unit and optical square mounted on an optical dock stand. Identical unit on opposite corner not shown.
2. K and E Jig Transit 9092-1A with Optical Square M7J-383 in place.
3. K and E Jig Transit 9092-1A (Optical Square M7J-383 is removed).
4. Portable Optical Tooling Bar. Transit can be positioned along any portion of its length.
5. Sight Level on K and E Stand for height measurement.
6. Optical Target and Cup Mount on stand.

Fig. 1 Portable Physi-Opt

A.



ical square mounted on an

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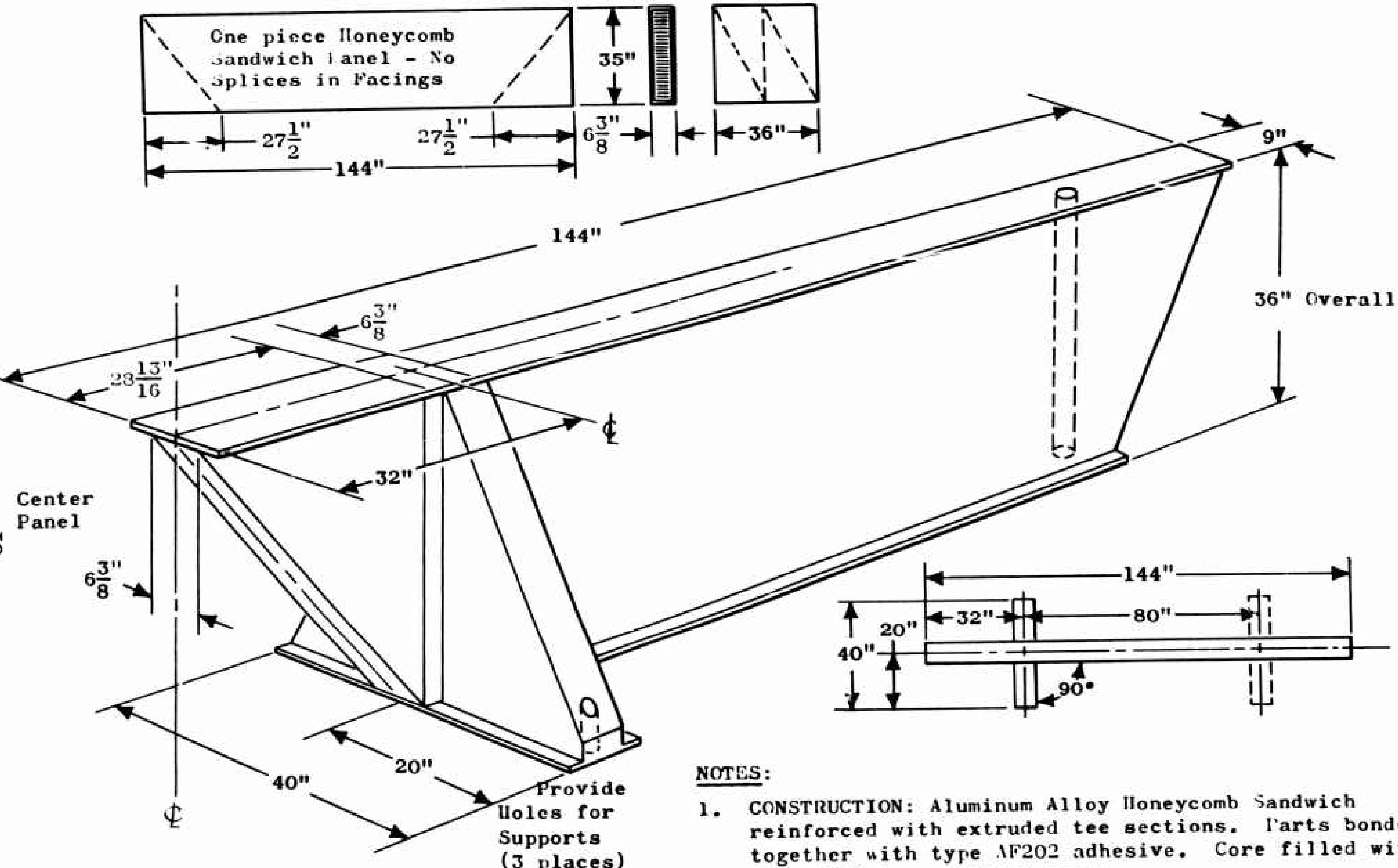
1 **Portable Physi-Optical Tooling Dock.**

B.



NOTES:

1. CONSTRUCTION: Aluminum Alloy Honeycomb Sandwich reinforced with extruded tee sections. Parts bonded together with type AF202 adhesive. Core filled with foam-fill in specified areas.
2. Prime Requisites: Stiffness, rigidity, stability, good damping qualities, lightness, straight, flat surfaces top and bottom for attaching adjoining members.

Fig. 2 Stand Sub-Assembly, TD7-1076B Sheet 1

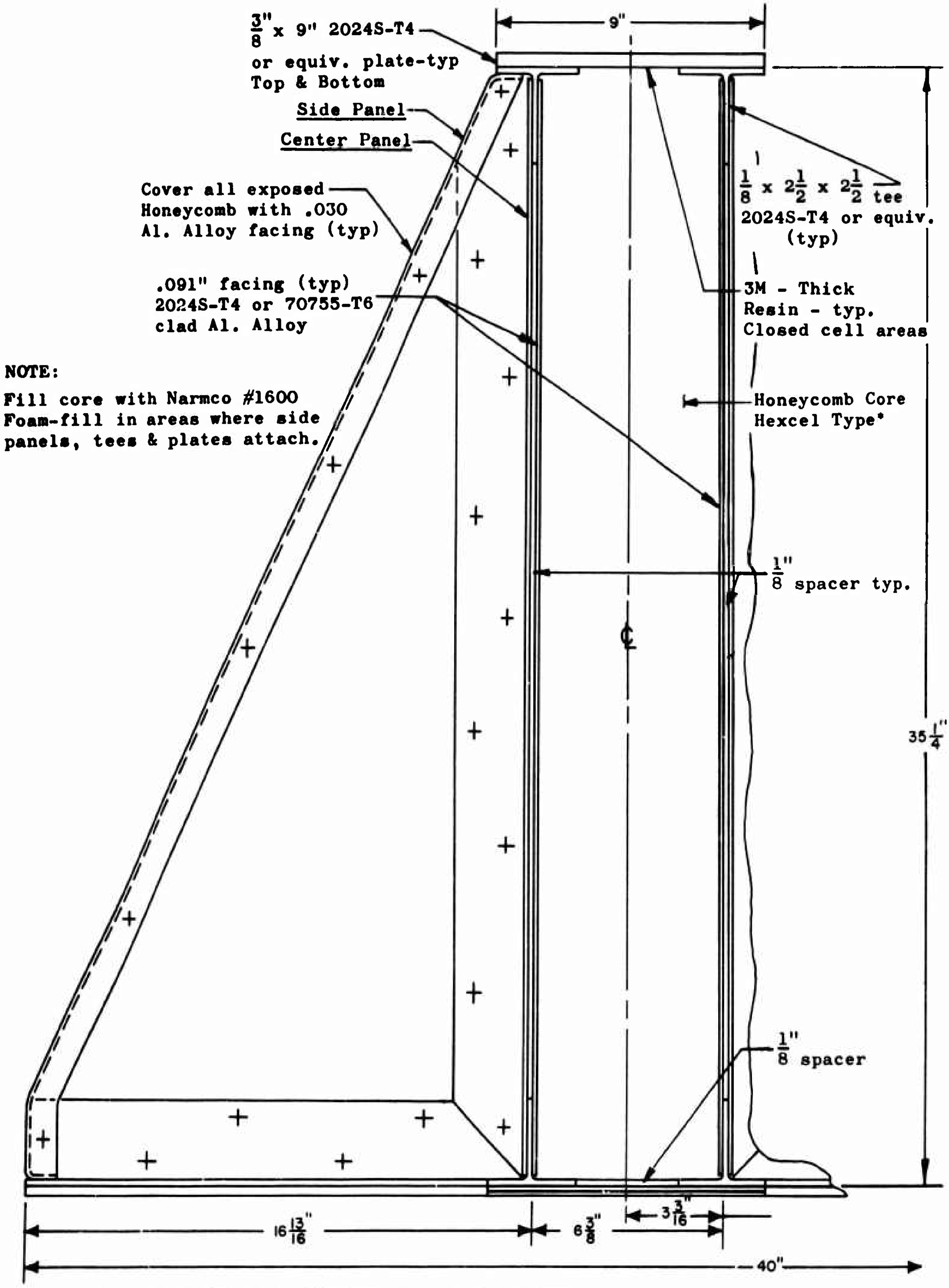
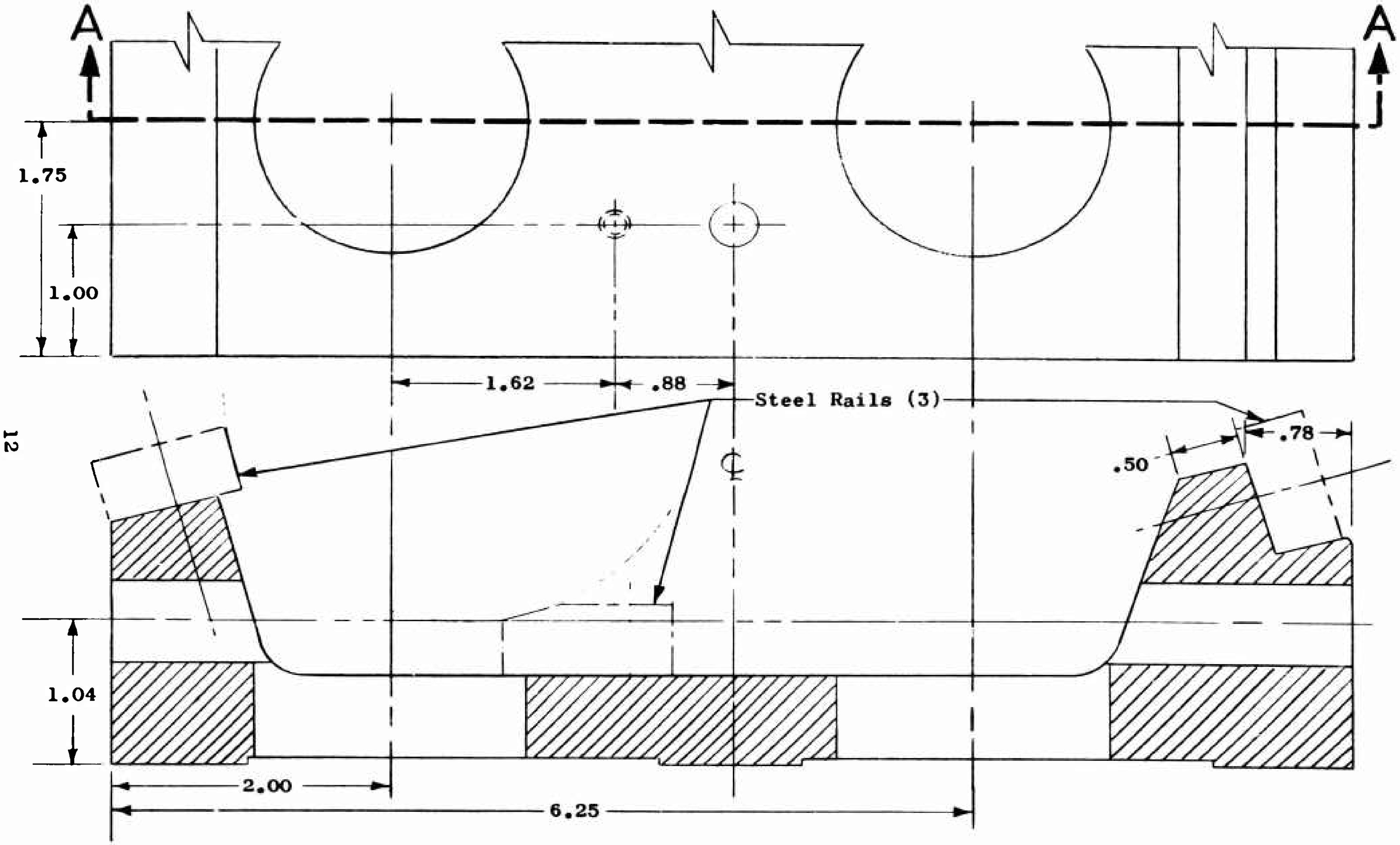


Fig. 3 Stand Sub-Assembly, TD7-1076B, Sheet 2



Section A-A.

Fig. 4. Machined Bed Way Assembly, Sectional View

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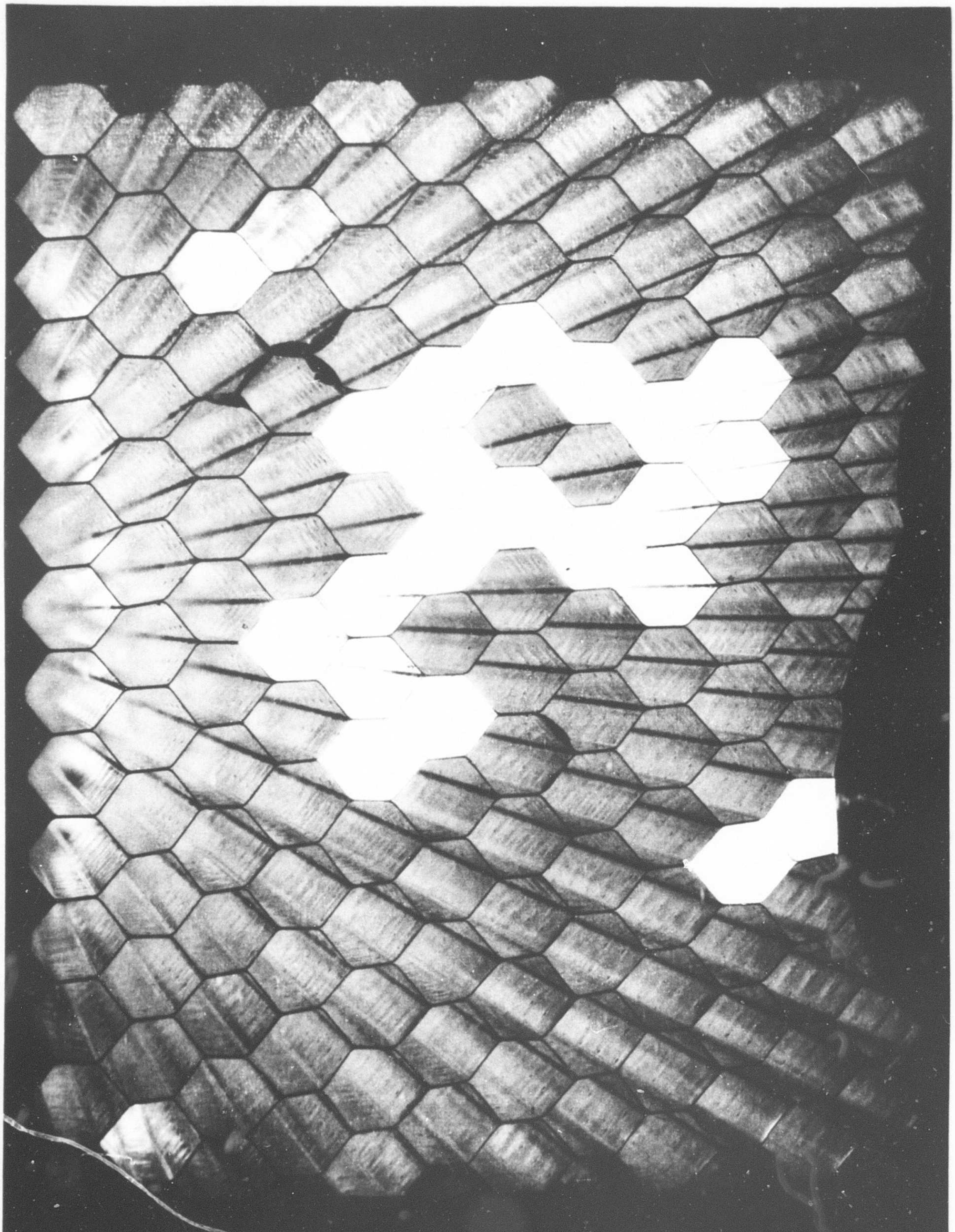

FIG. 5 "Hexcel" Honeycomb Core

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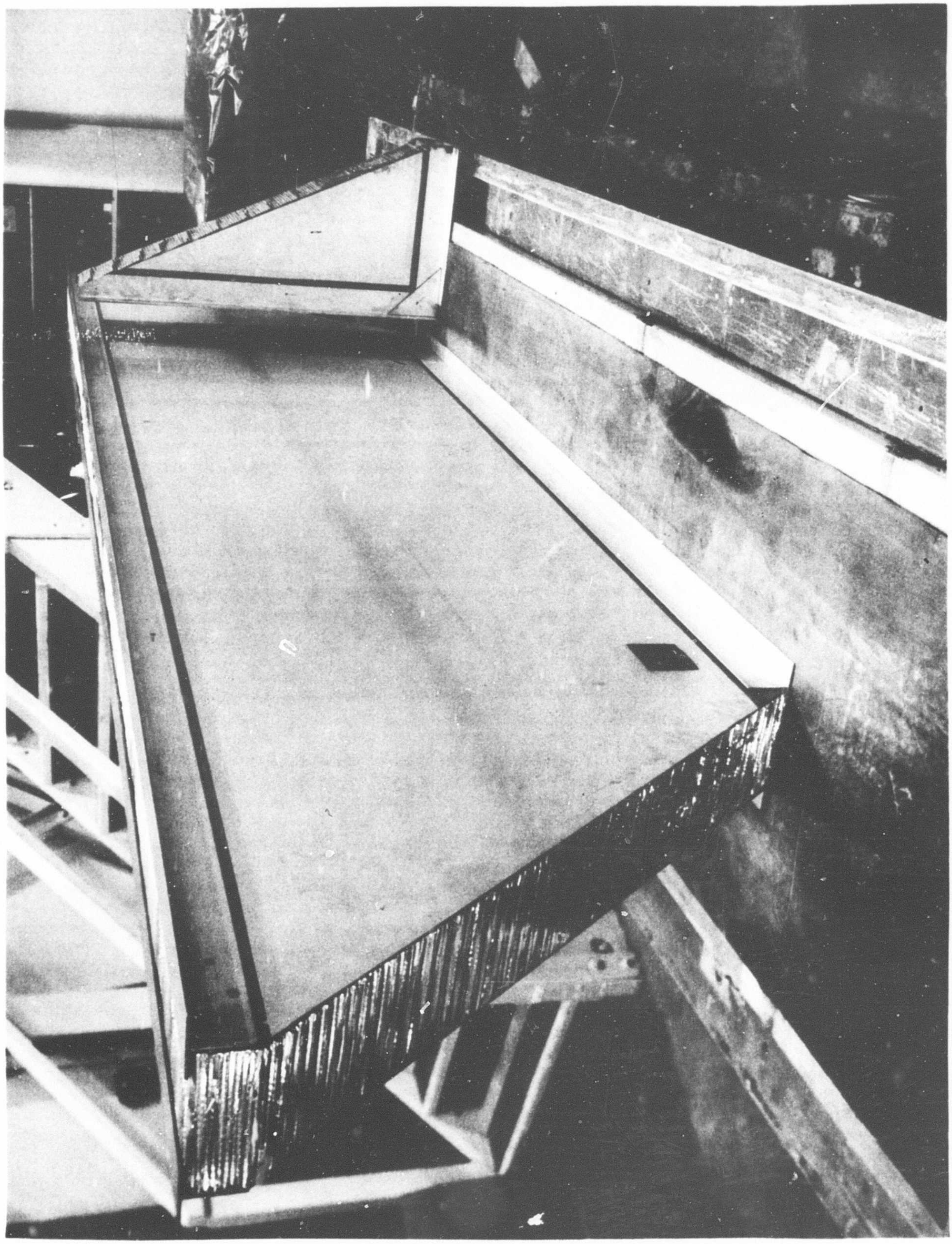

FIG. 6 Honeycomb Bonded Bar Components

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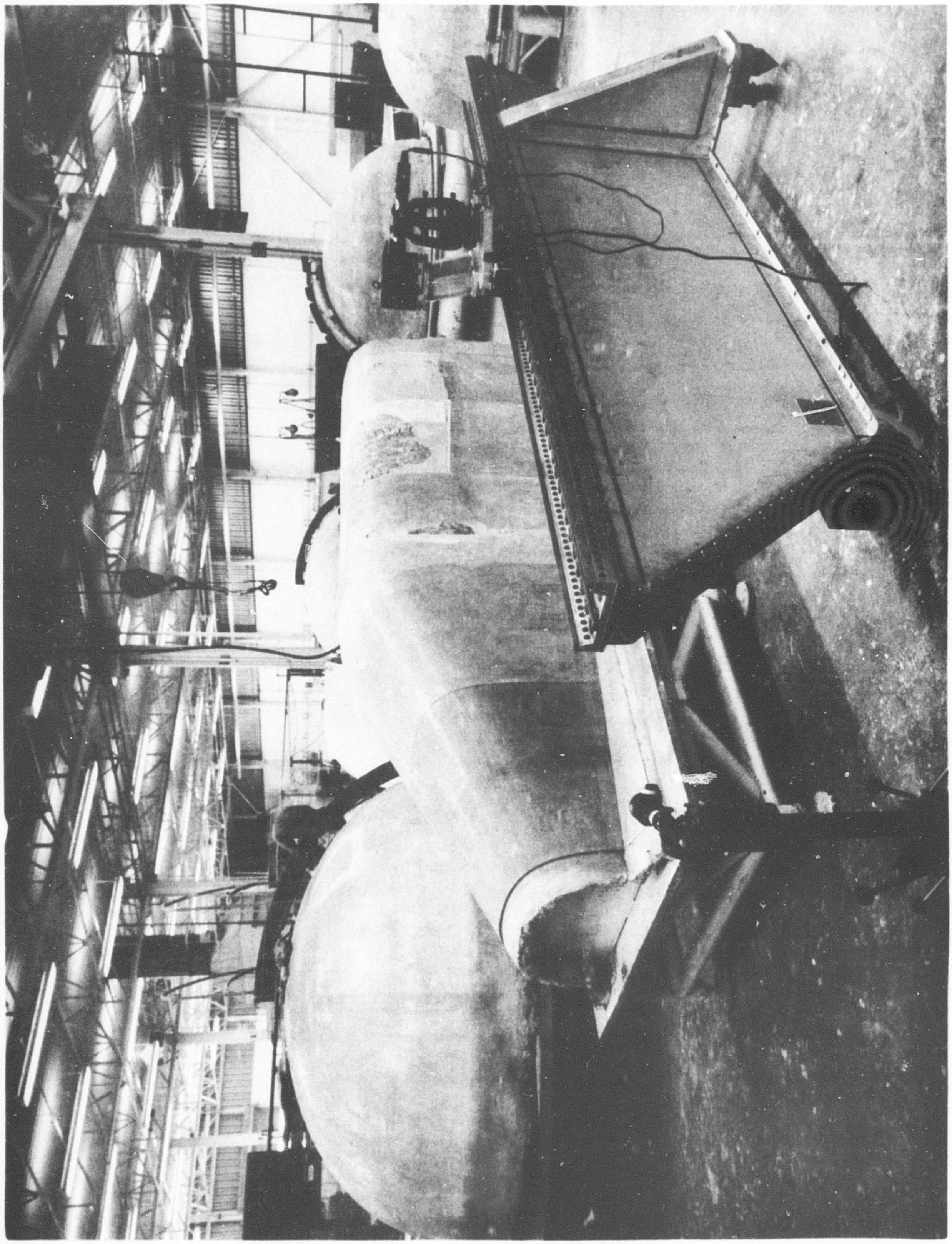

FIG. 7 Completed Honeycomb Bar Set-up

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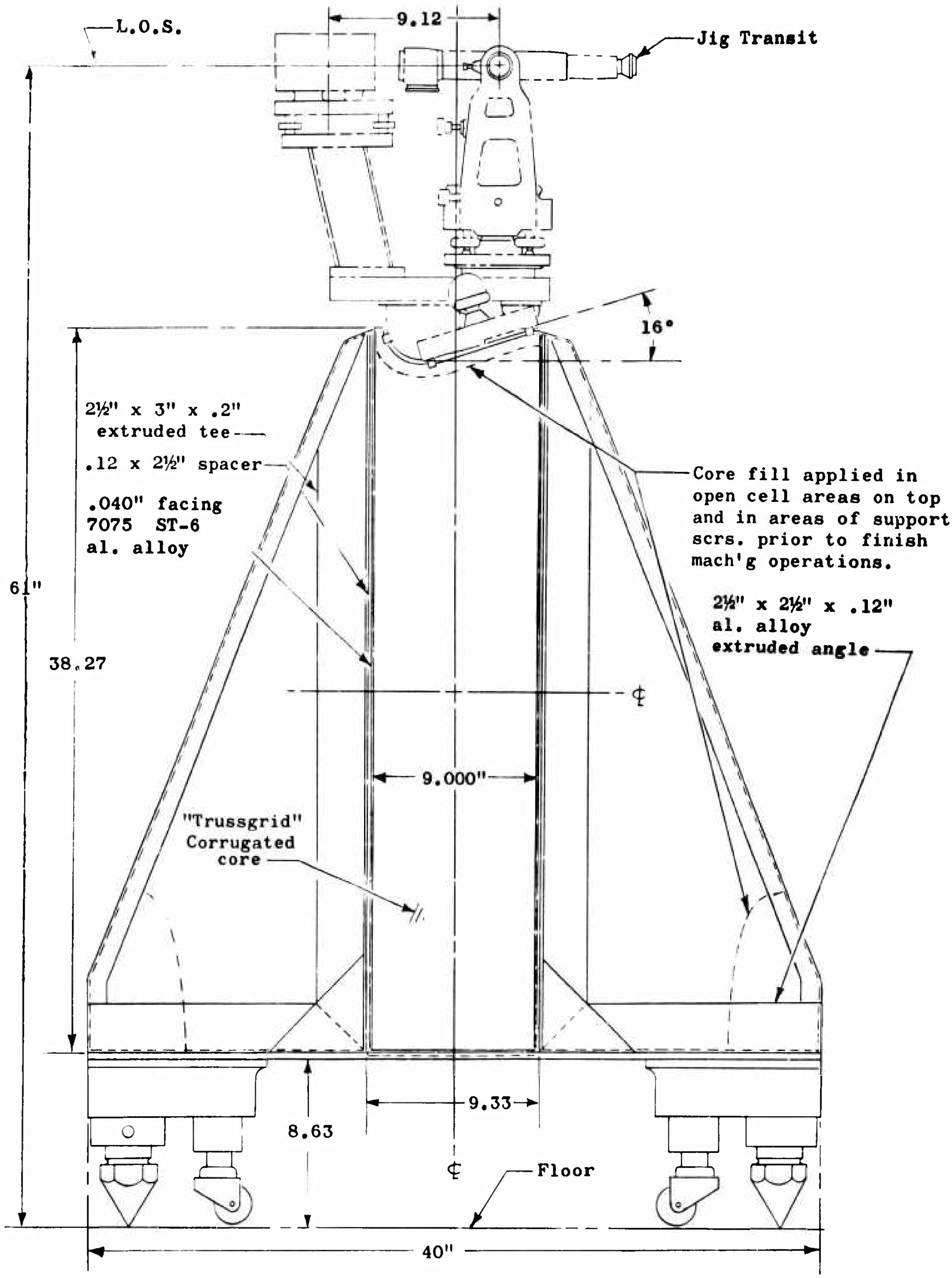

Fig. 8 Prototype Optical Tooling Bar, "Trussgrid" Corrugated Core.

FIG. 9 Fabricating "Trussgrid" Corrugated Core,- Straight Cust by Bandsaw

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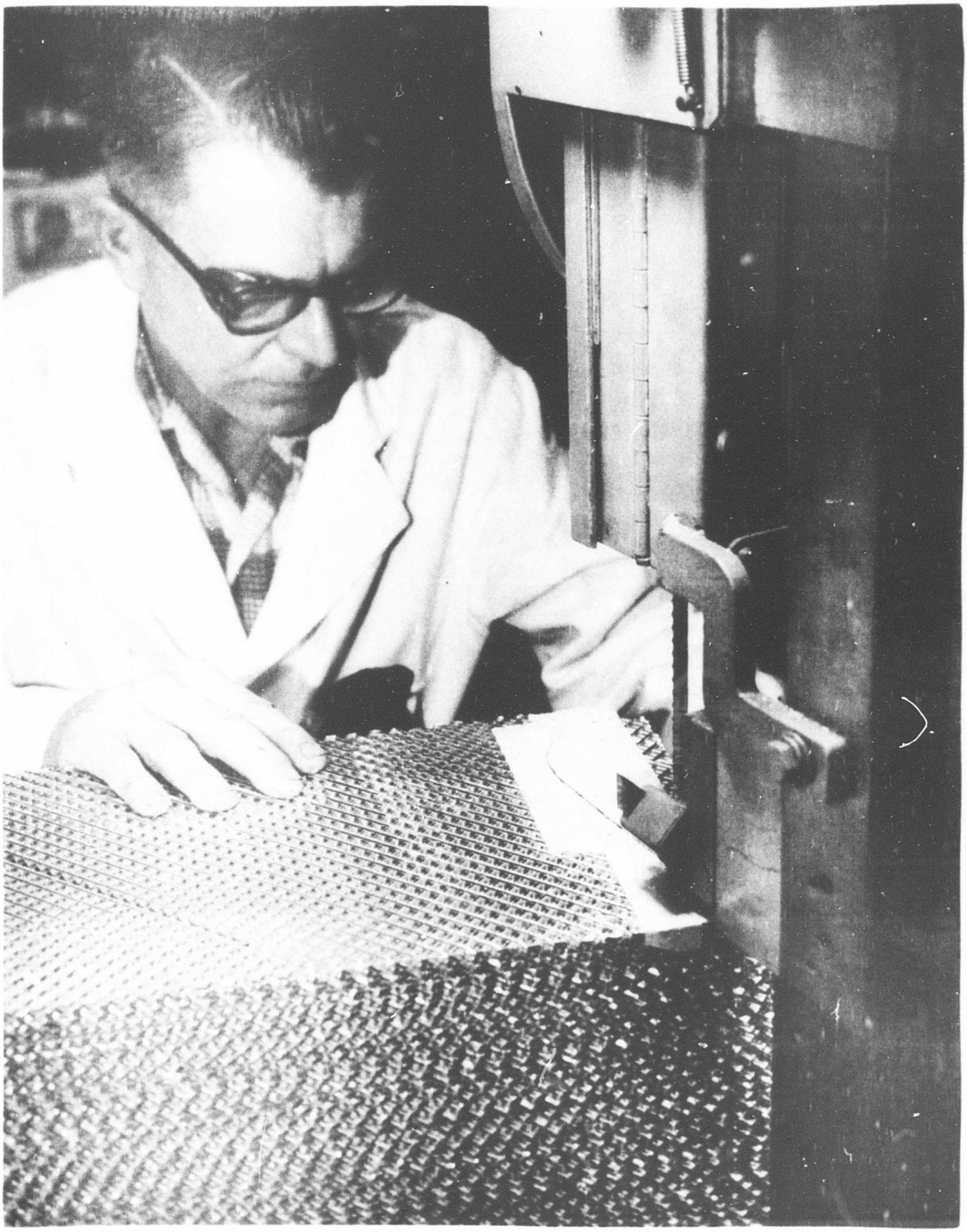

FIG. 10 Fabricating "Trussgrid" Corrugated Core,-Curved Cut

FIG. 11 "Trussgrid" block showing Contured Cut

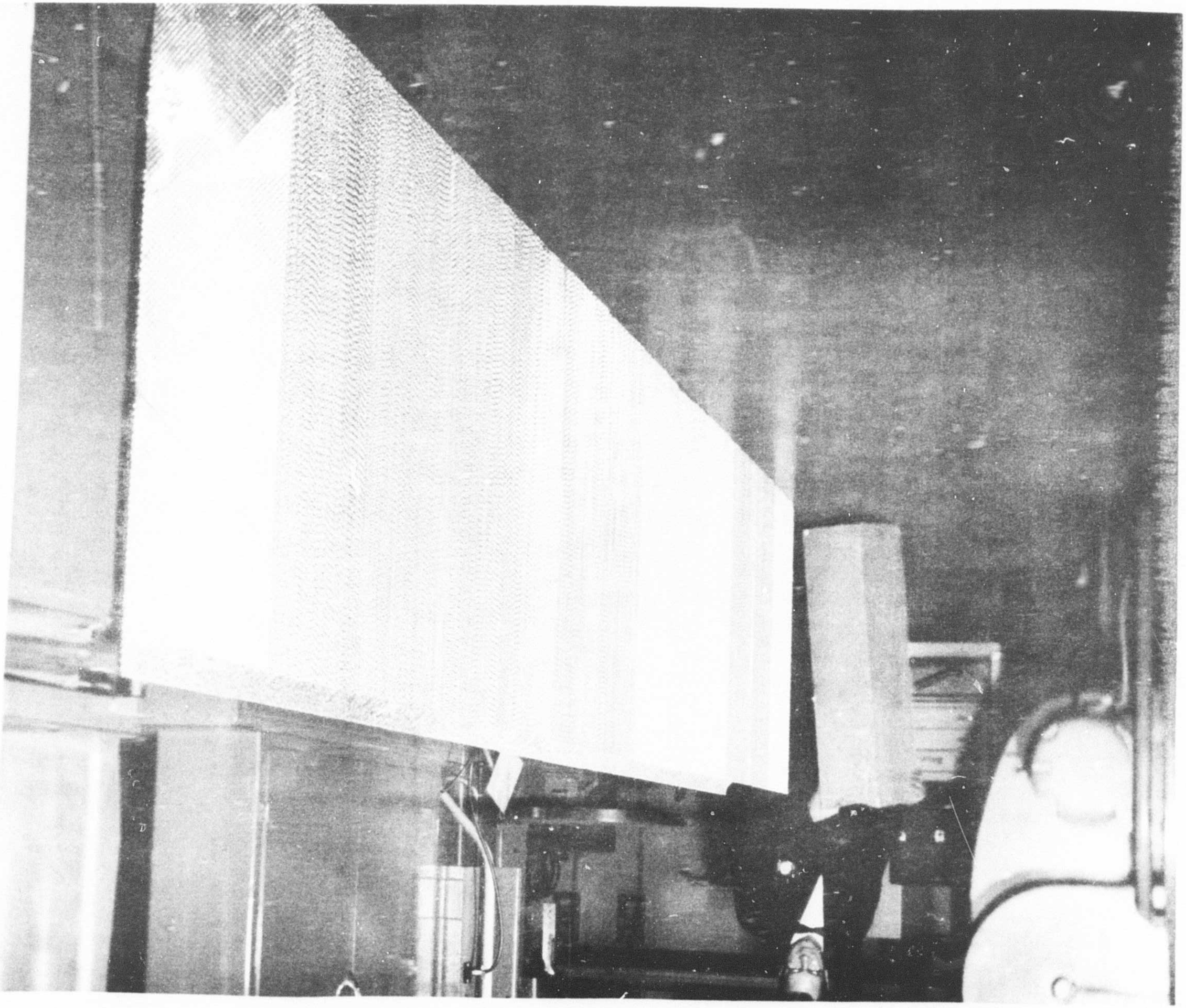

FIG. 12 Fabricated "Trussgrid" Core Blocks Prior to Bonding into Sandwich Beam Assembly.

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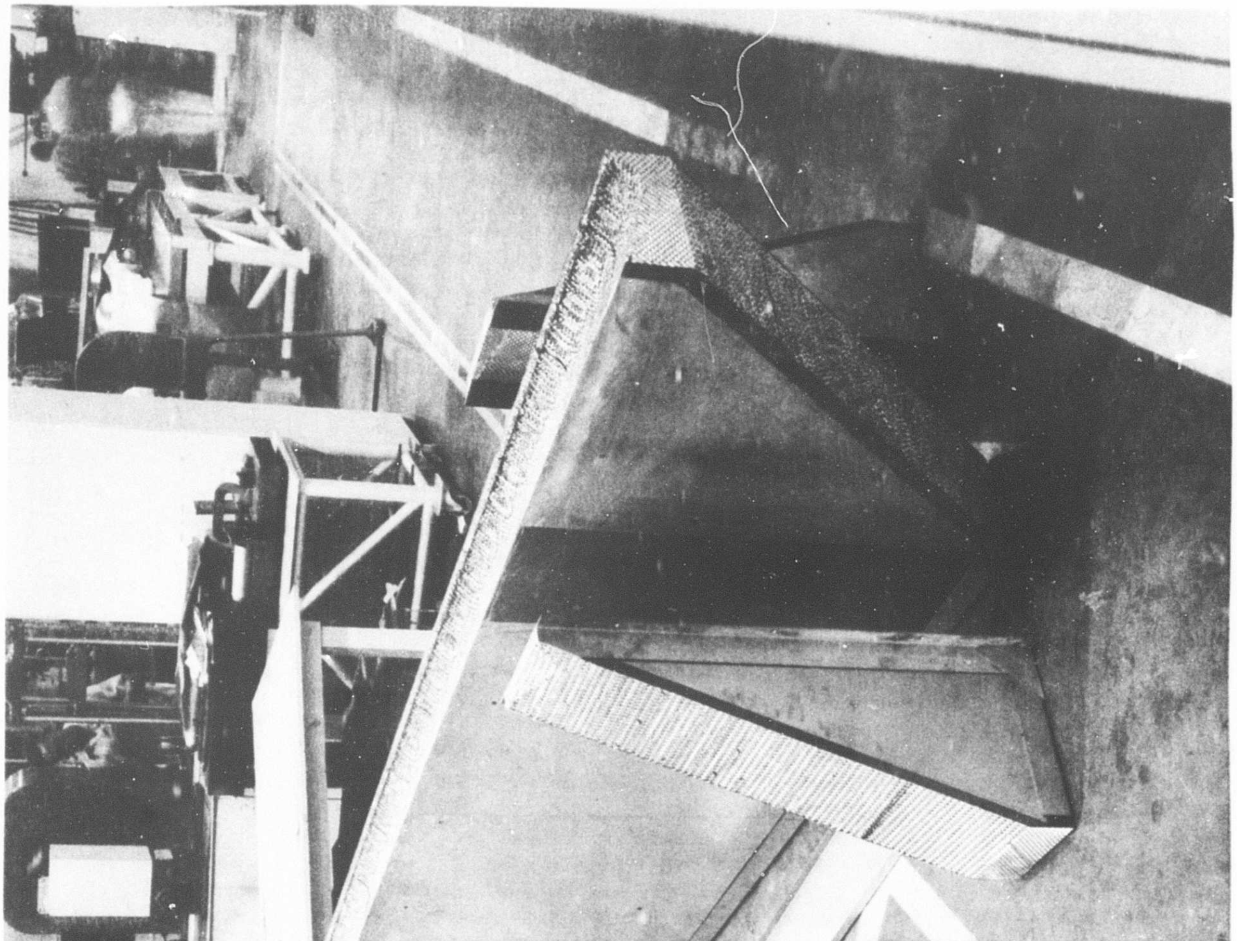

FIG. 13 "Trussgrid" Core Beam Assembly, Center and Side Panels, etc.

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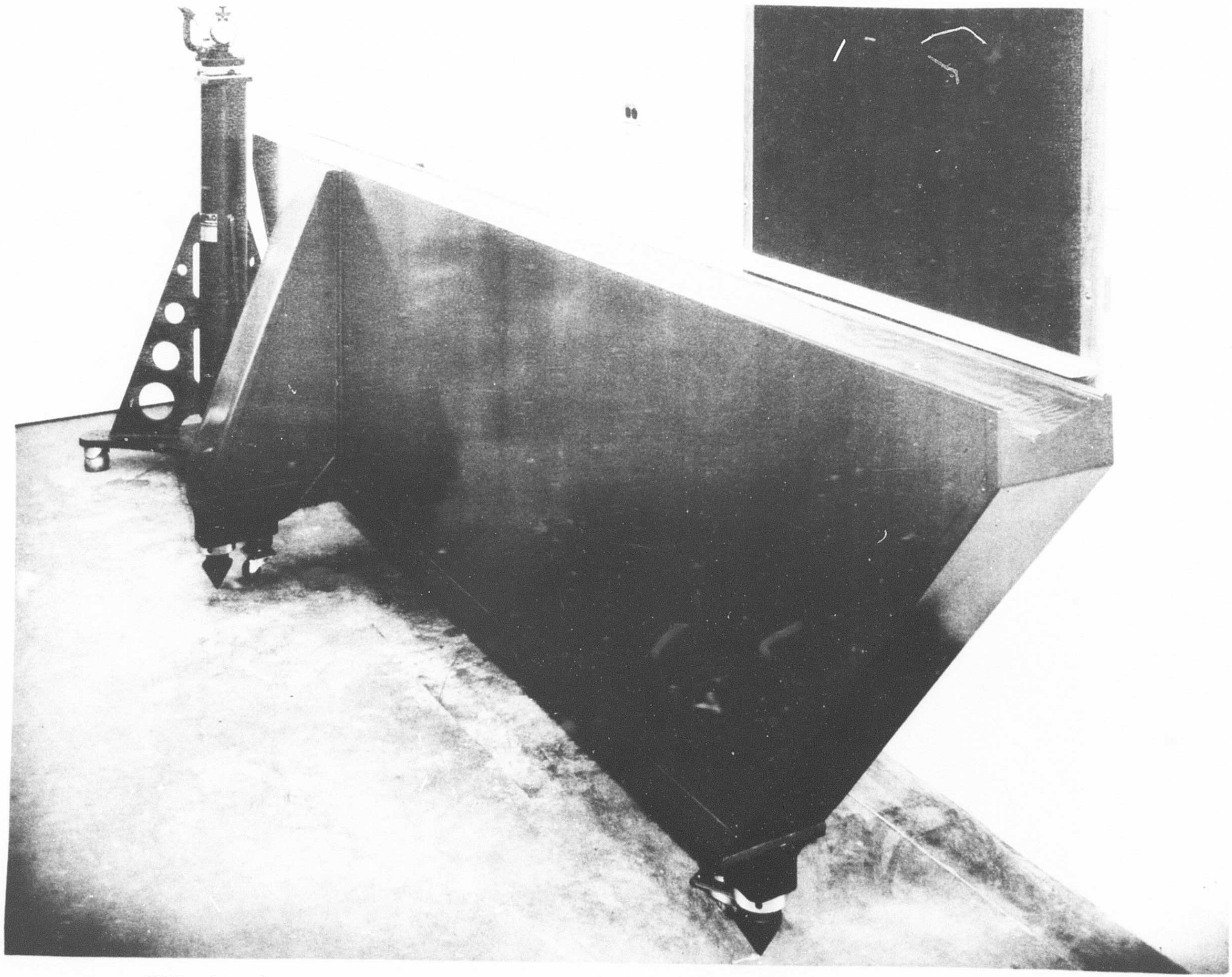

FIG. 14 Completed Optical Tooling Bar, Sandwich Construction, "Trussgrid" Corrugated Core.

22

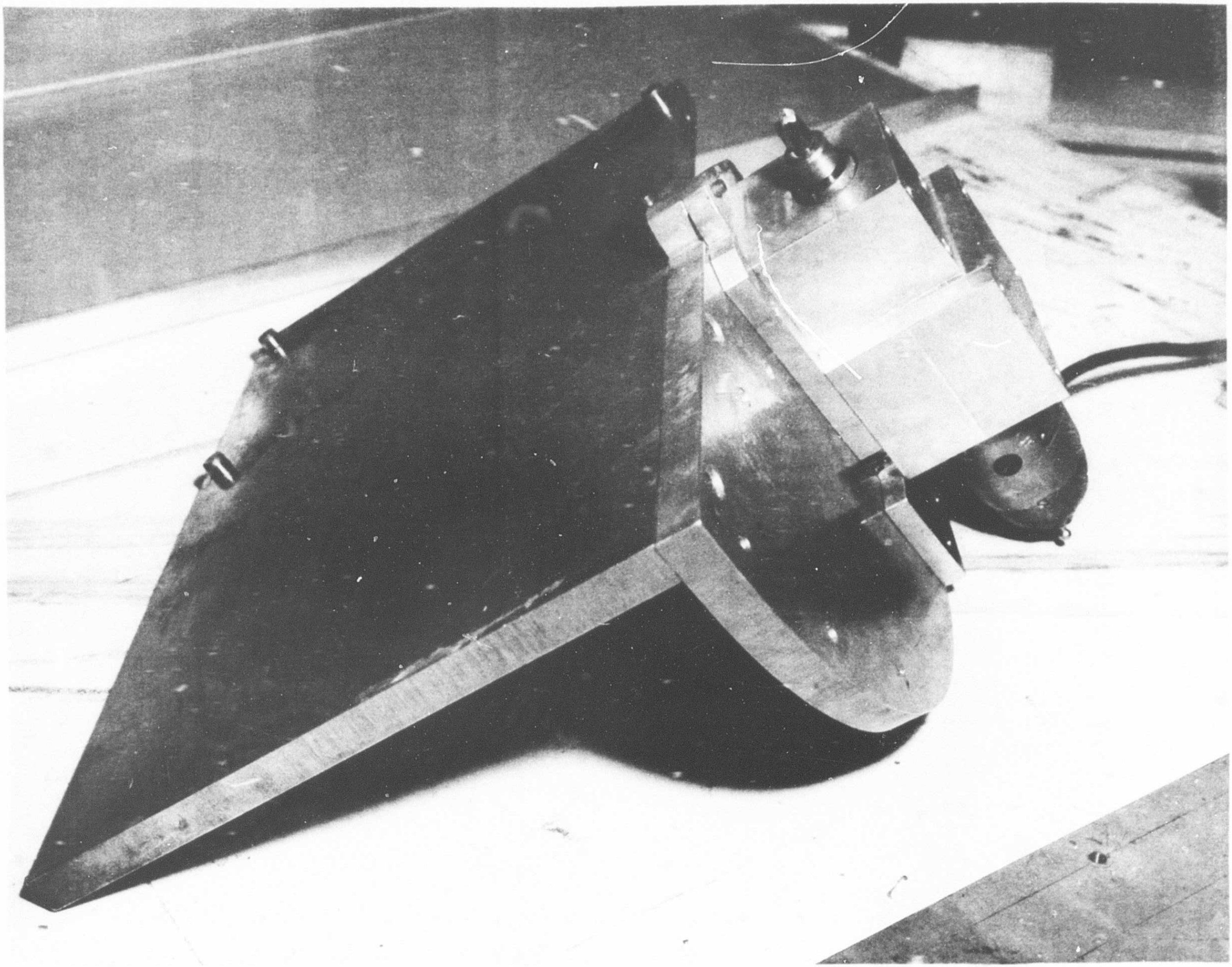

FIG. 15 Mill Fixture (MLFX) for Milling Bed Rail Grooves in Core - (Bottom View).

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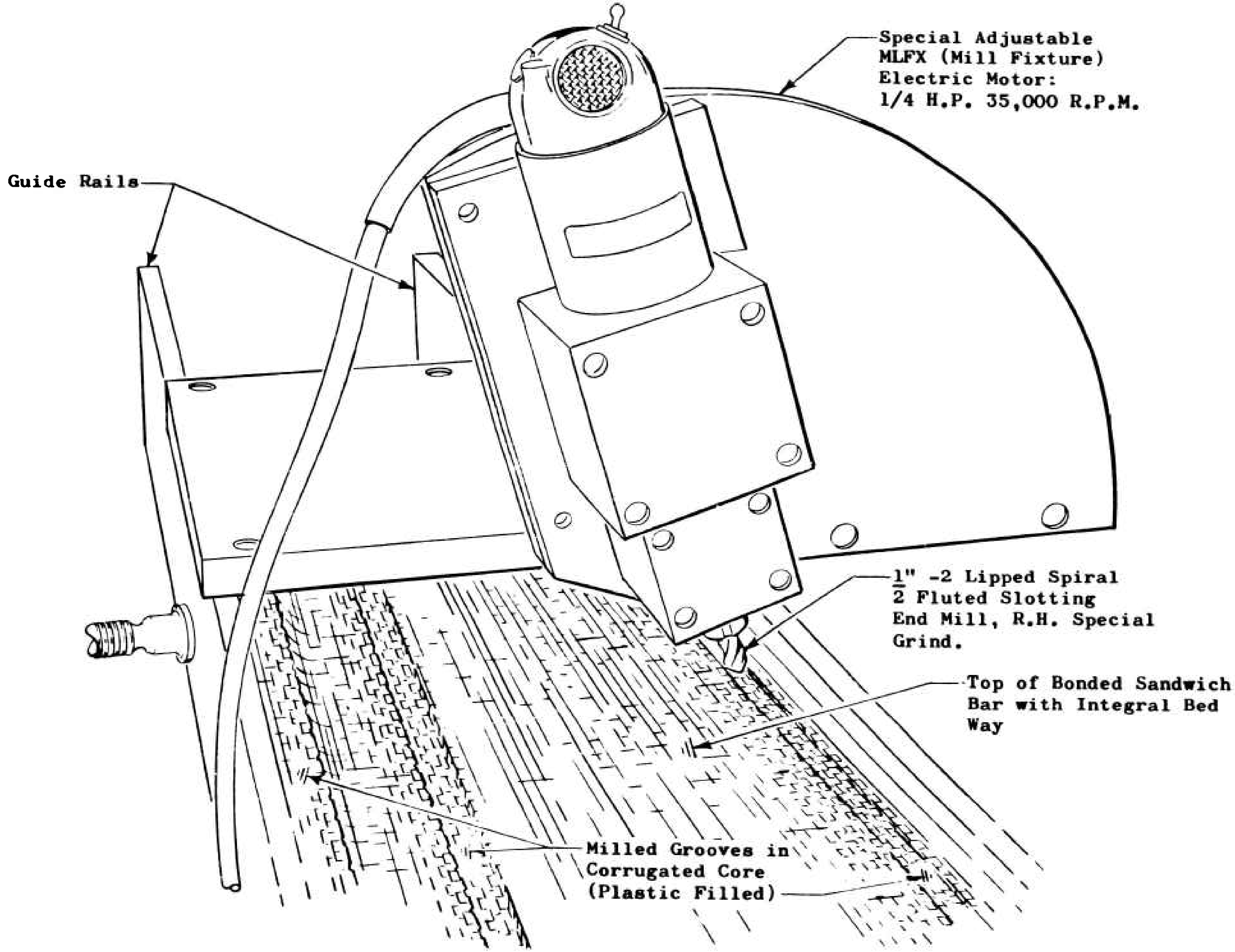

Fig. 16 Milling Fixture in Operation on Guide Rails Secured to Bar
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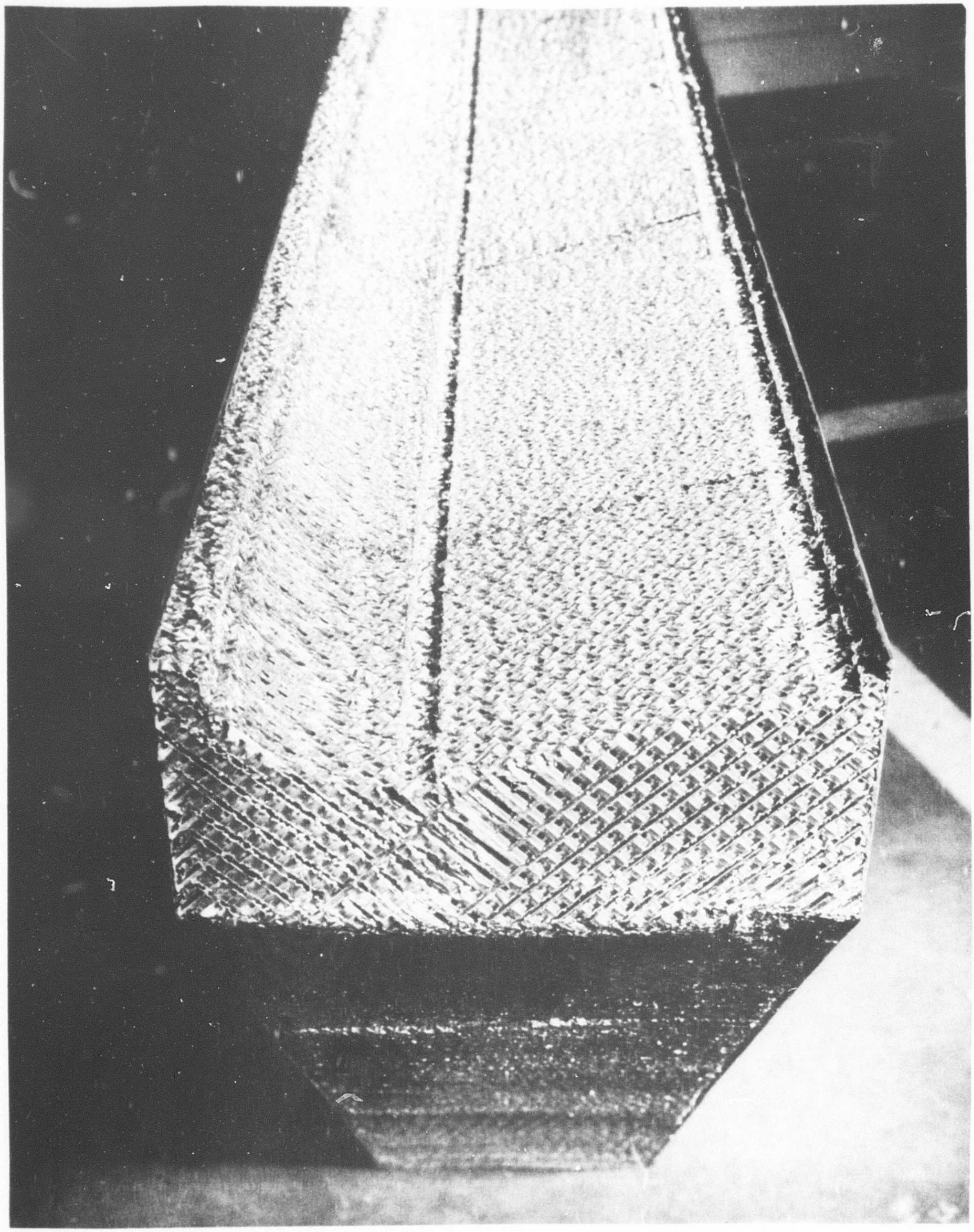

FIG. 17 Milled Grooves in "Trussgrid" Core to Receive (3) 3/8" x 1/2" x 12 ft. long Steel Rails.

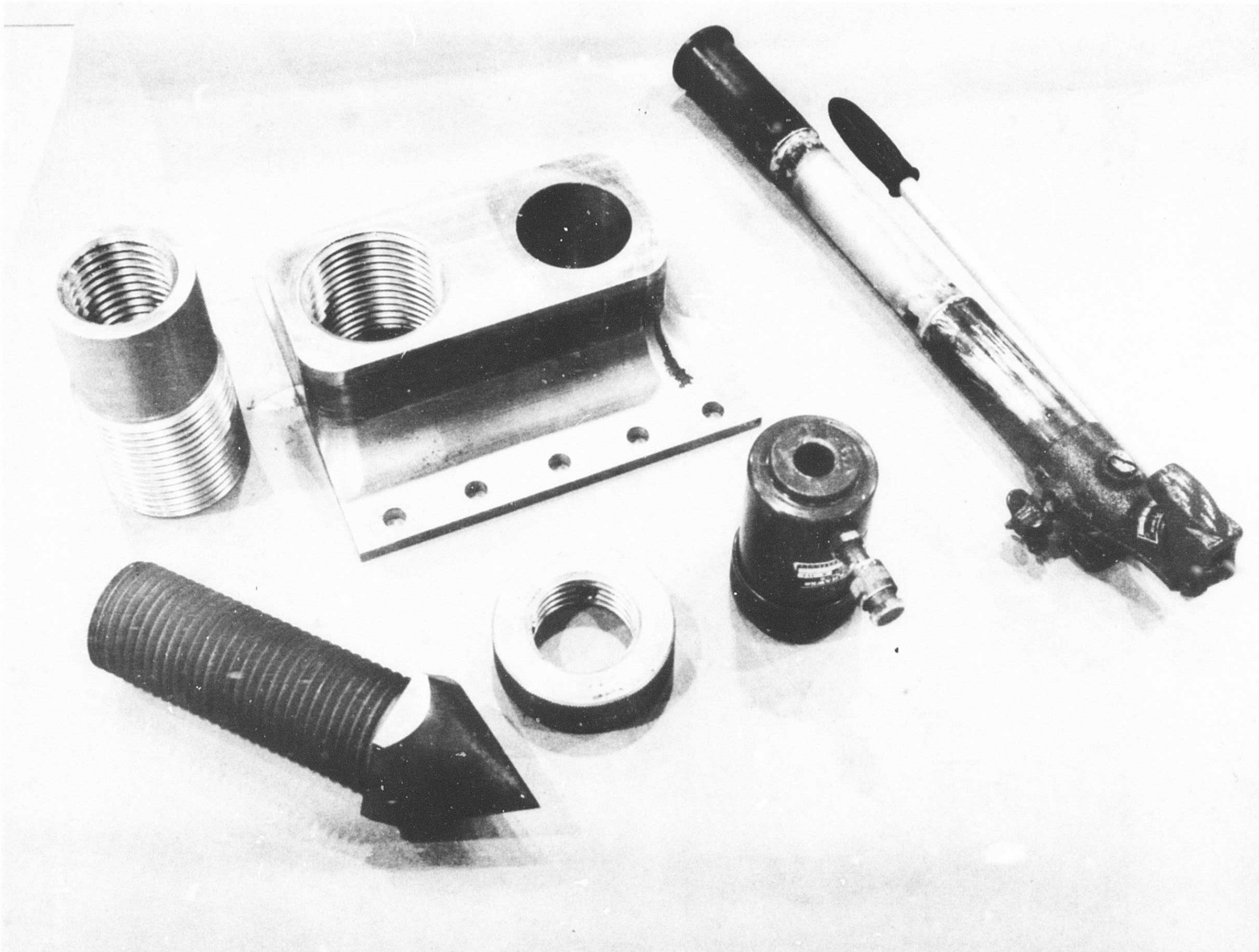

FIG. 18 Hydraulic Pump, Ram and Leveling Screw Support Units.

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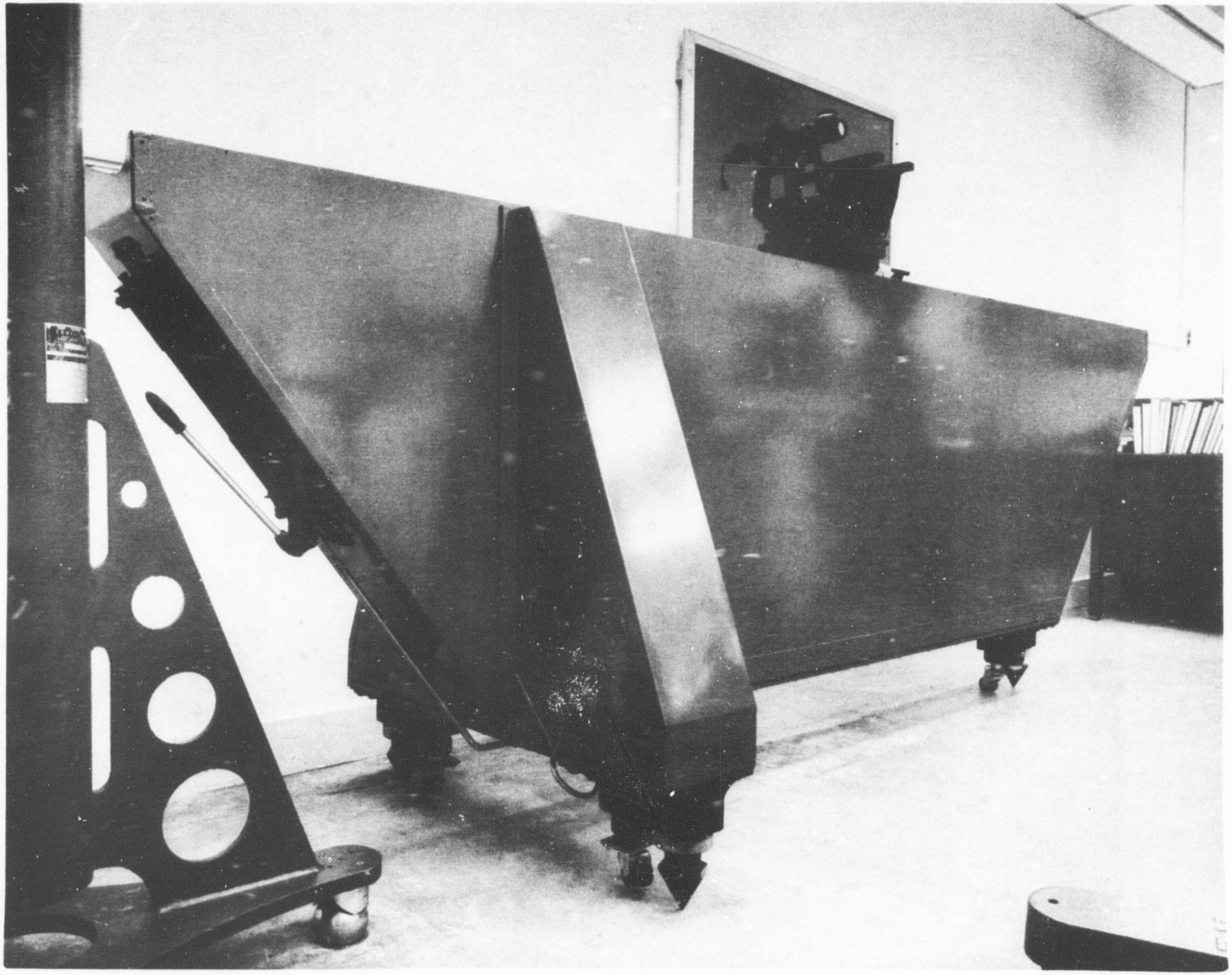

FIG. 19 Hydraulic Lift System - Casters Retracted.

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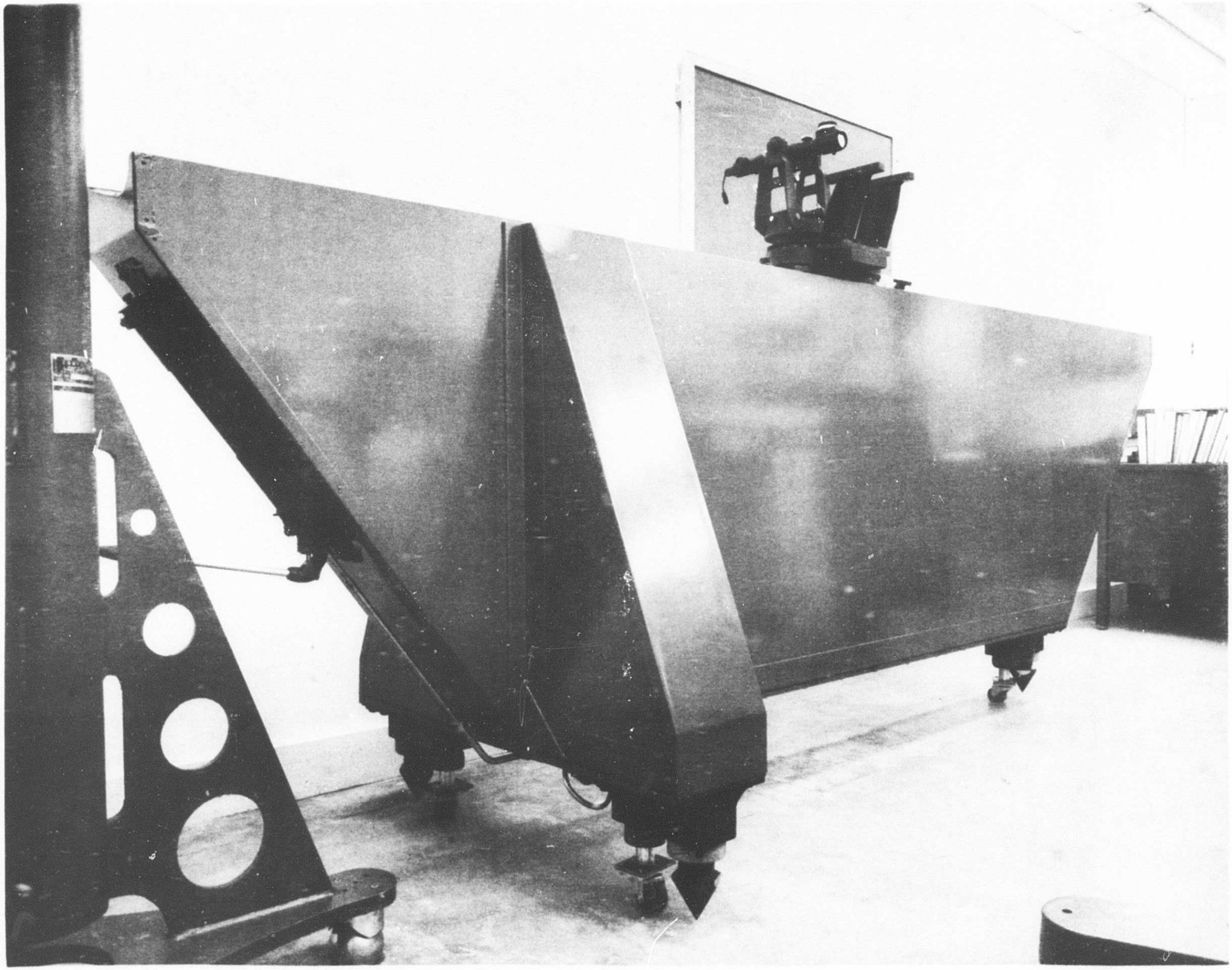

FIG. 20 Hydraulic Lift System, - Casters Down

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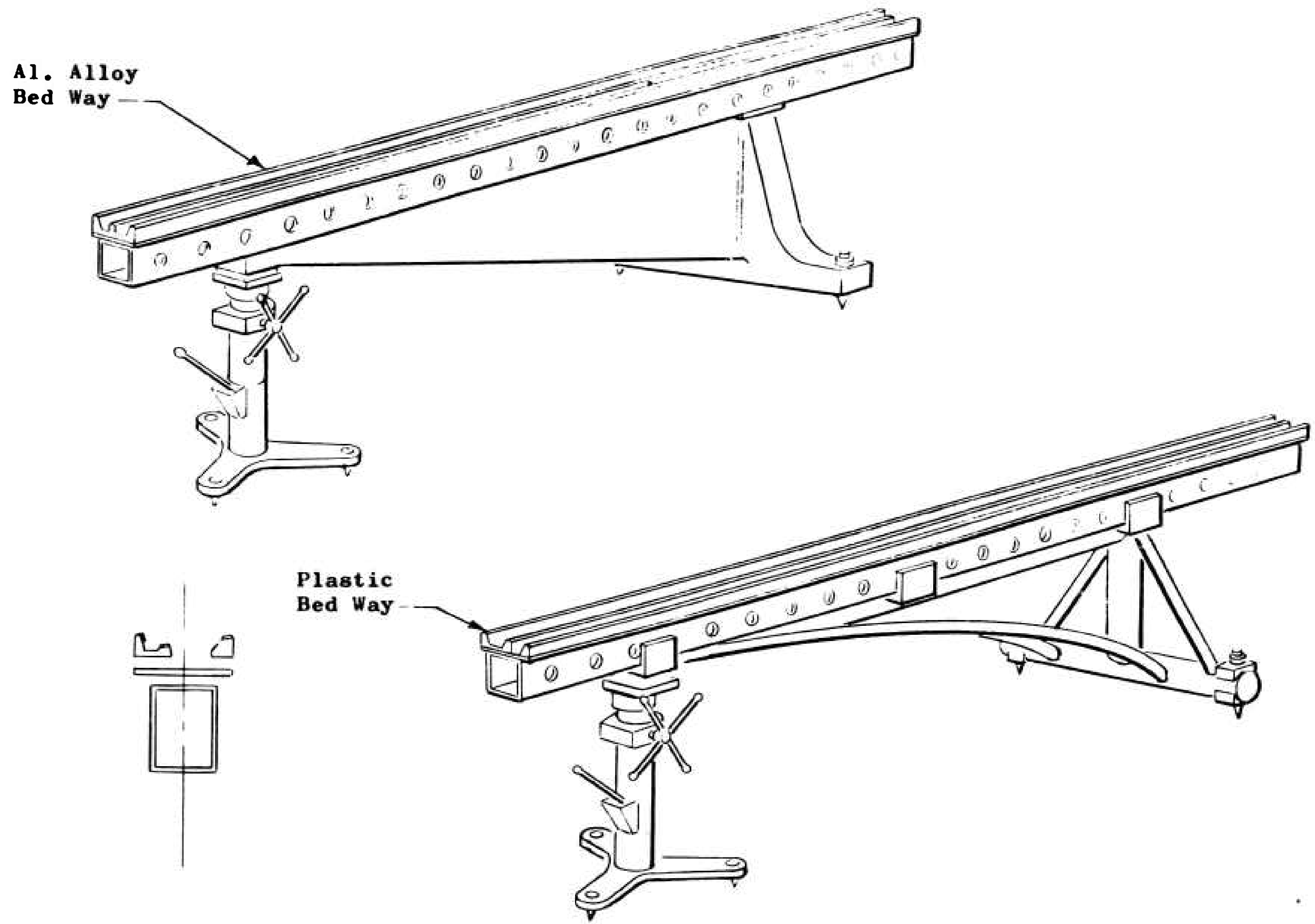

Fig. 21. Trundle Type Bars with K&E Instrument Stands

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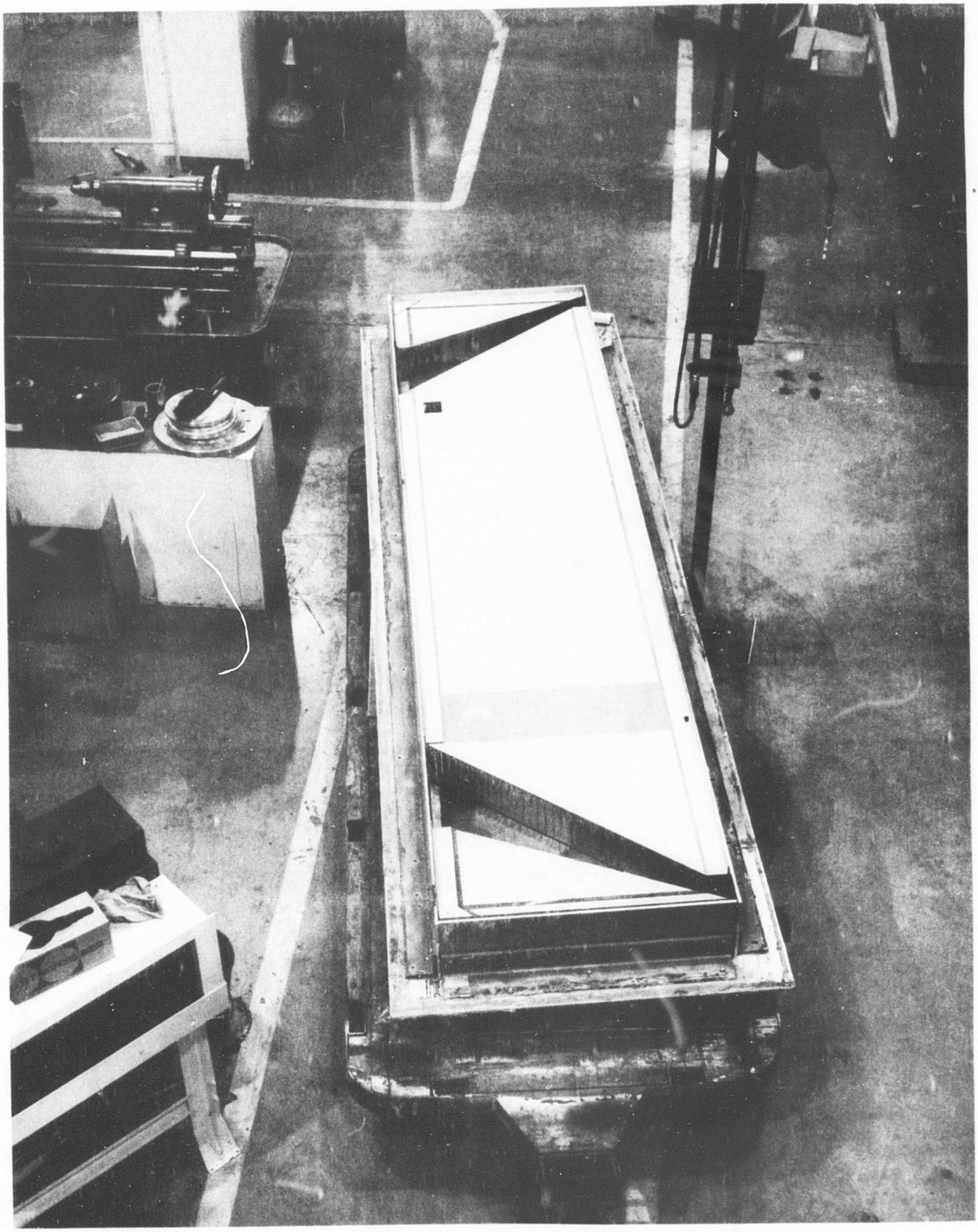

FIG. 22 BNTO Bonding Tool TD7-1076B and Honeycomb Bar Assembly in Place.

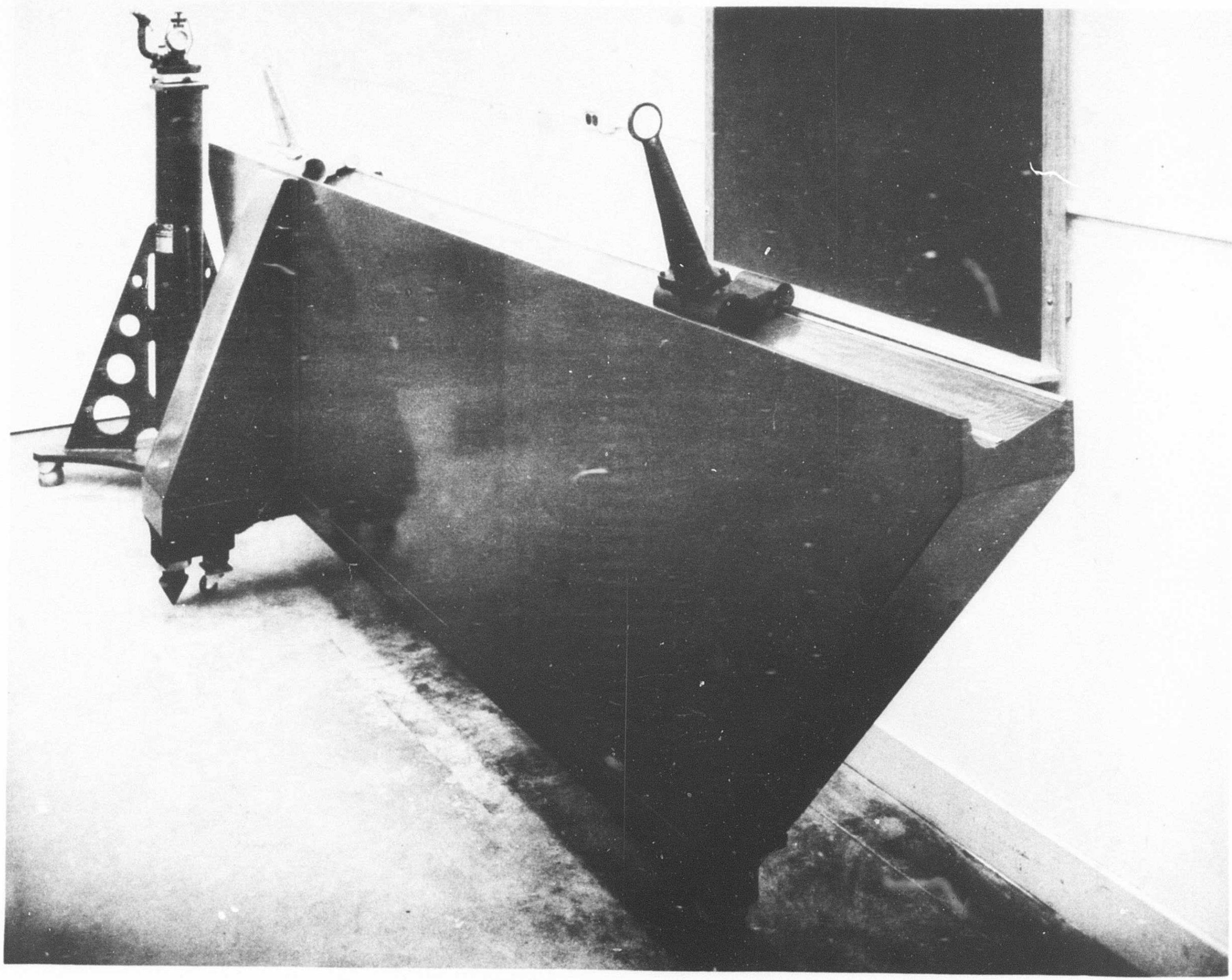

FIG. 23 "Trussgrid" Optical Tooling Bar with Targets in Place and Aligned with Offset Line of Sight Target on Corner Stand.

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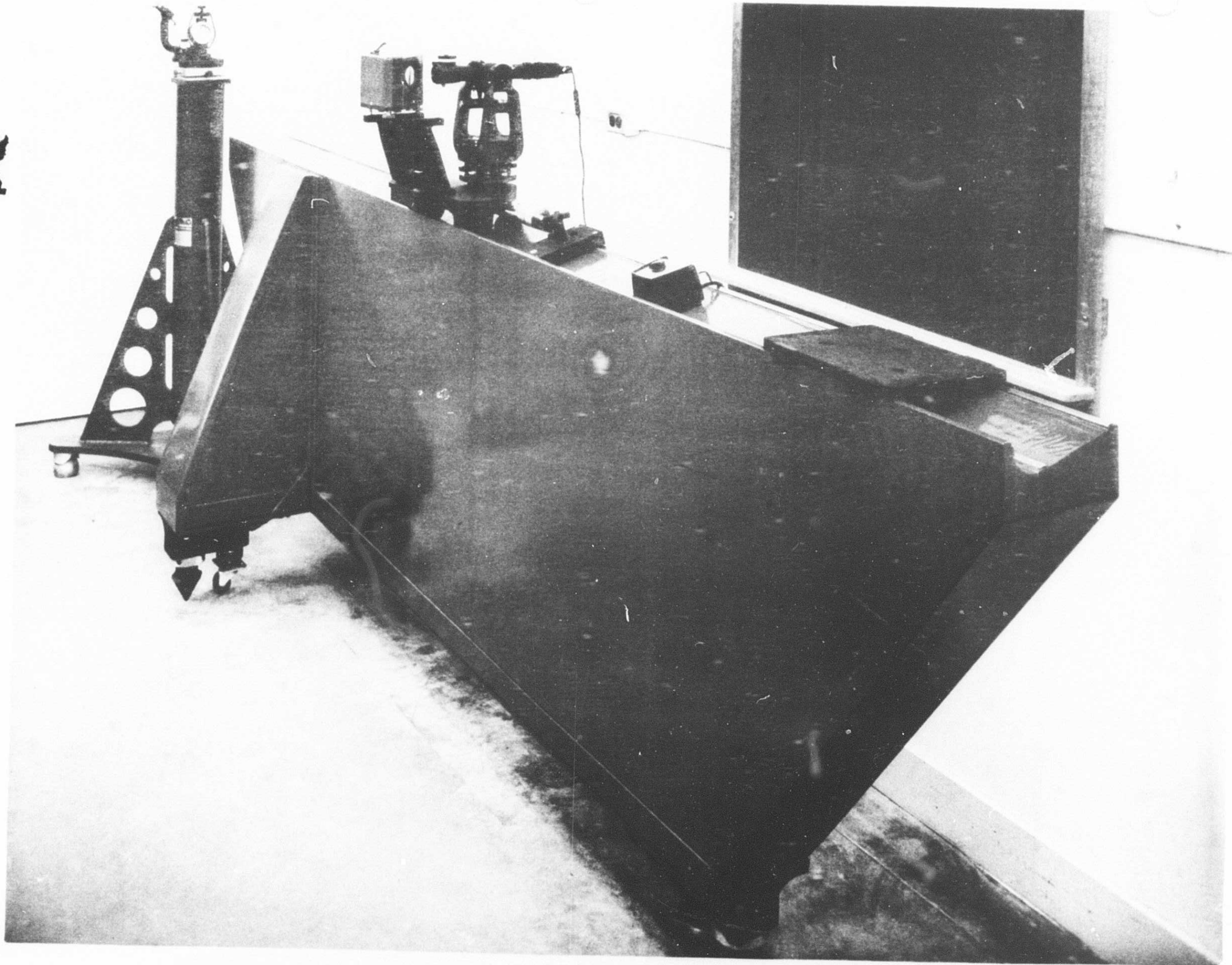

FIG. 24 "Trussgrid" Optical Tooling Bar with Jig Transit and Optical Square. Transit Set Normal to Offset Line of Sight.

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